A GEOCHEMICAL STUDY OF THE KALAMAZOO PORPHYRY COPPER DEPOSIT, PINAL COUNTY, ARIZONA

by

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Abstract

The region encompassing the southwestern United States and the adjoining sections of northern Mexico contains the highest density of known porphyry copper deposits in the world. It seems likely that most of the exposed porphyry copper deposits that exist in this region have now been found. As a consequence, exploration for new deposits of this type requires the development of techniques or approaches capable of detecting mineralized rock that does not crop out. This search for new approaches has created renewed interest in whole-rock geochemistry. To learn more about the geochemistry of porphyry copper deposits and the potential of rock geochemistry in the exploration for blind porphyry copper deposits, a study was made of a deposit of this type: the Kalamazoo deposit near San Manuel, Pinal County, Arizona.

Three major geologic units are present in the area of the Kalamazoo deposit and the nearby San Manuel deposit. These units include (1) a Precambrian quartz monzonite (Oracle Granite of Peterson) batholith, (2) a Cretaceous monzonite porphyry stock that intruded the batholith, and (3) Cretaceous and Tertiary conglomerates and sedimentary breccias and intercalated volcanic rocks. The Kalamazoo and San Manuel deposits are offset, rotated segments of a single mineral deposit genetically and spatially associated with the Cretaceous stock. The deposits occur both in the Precambrian quartz monzonite and in the Cretaceous monzonite porphyry.

Samples of cores and cuttings from four holes drilled through the Kalamazoo deposit were analyzed for bulk density and for as many as 62 different elements. Two of the holes penetrated both the alteration zones (propylitic to potassic) and the ore zone (+0.5% Cu) near the top of the deposit as it existed before tilting. The other two holes intersected the ore zone near its roots.

The distributions of values for bulk density were compared to the distributions of concentrations for most of the elements. The variations in bulk density correlate directly and most closely (and at a highly significant level) with variations in concentrations of sulfur and iron. These correlations suggest that the density values are basically a measure of the pyrite content of the samples.

Of the 62 elements determined, at least 20 show distinct zones of high or low concentrations that are spatially related to the alteration zones, the pyrite zone, and the copper ore zone. Minor or trace elements provide more useful information than do most of the major rock-forming elements.

Some of the elements determined in this study, or the ratios of certain elements, may be useful in identifying the zoning of specific minerals or mineral groups; for example, the ratio of Fe/Mn (and possibly the ratios of Fe/Mg and Fe/Ca) can be used to separate those iron anomalies related to pyrite in the pyrite zone from those related to other minerals. The spatial distribution of other elements or other element ratios may be useful for defining zones containing high concentrations of less obvious minerals that are more difficult to identify in either hand specimens or in thin sections than is pyrite.

Examination of depth–versus–concentration curves for the 20 selected elements indicates that the curves for these elements can be classified into one or more of four types. Elements forming Type 1 curves (B, Ba, Sr, Li) have their highest concentrations in the lower half of the ore zone or below the ore zone in the barren or low-grade core of the de-

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posit. Type 2 curves include those elements (Cu, Mo, Ag, Au, Te, K) concentrated in the copper ore zone. Type 3 curves include those elements (Co, V, Se, Fe, S, Rb, Au, Te) that have positive anomalies in aureoles outside the ore zone. Type 4 curves include those elements (Mn, Zn, Pb, Tl) that seem to form negative anomalies relative to the ore zone. It is probable that Type 4 curves are really Type 3 curves having positive anomalies in aureoles well beyond those of the Type 3 elements.

A study of the locations of intervals of high element concentration and of the locations of coincidences of element concentration peaks suggests that a three-dimensional geochemical model of the Kalamazoo deposit can be synthesized. The elements forming Type 2 curves probably are concentrated in a roughly cylindrical zone surrounding the core zone. The elements forming Type 3 curves seem to occur in four different aureoles that surround the ore zone at varying distances. With increasing distance from the ore zone, the elements in these four aureoles are (1) Co, V, and Se; (2) Fe and S; (3) Rb; and (4) Au and Te. The first three of these aureoles seem to occur concentric to the ore-zone aureole. There are two separate zones in which the concentrations of both Au and Te are high; the inner zone coincides with the cylindrical ore zone, whereas the outer one seems to be conical in form, expanding rapidly outward with depth. The elements forming Type 4 curves probably occur in the outermost aureoles.

Geochemical exploration programs using whole-rock samples must take into account the effects of chemical weathering. Of the 20 elements selected for this study, Cu, Zn, and Rb were the only ones that were not generally depleted by weathering processes. Less complete information suggests that Au, Ag, Pb, Te, and Se were also relatively unaffected by weathering.

At Kalamazoo, the concentrations and spatial positions of a suite of ore-related elements could have been used to locate this blind deposit. If other porphyry copper deposits with similar alteration-mineralization zoning also exhibit chemical zoning similar to that found at Kalamazoo, then multielement zoning should be useful in the search for other blind deposits contained within exposed rock bodies.